

Final Report submitted to  
NOAA's Human Dimensions of Global Change Research (HDGCR) Program

**Project Title:** HUMAN STRATEGIES FOR COPING WITH ENSO AND THE GROWING FLAMMABILITY  
OF FORESTS IN AMAZÔNIA

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## I. Preliminary Materials

### A. Project Abstract:

This project undertook an analysis of human coping strategies to ENSO-related drought, in light of the growing flammability of forests in two regions of the Brazilian Amazon. Recent studies suggest that 60% or more of areas currently experiencing burning in the Brazilian Amazon burn unintentionally. In the past, tropical moist forests were sufficiently resistant to fire disturbance because closed canopies maintained high moisture levels in the understory, suppressing fire penetration at ground level. Fragmentation of forests, selective logging, and other anthropogenic driving forces have opened the canopy and created warmer and drier conditions at ground level that are more conducive to the spread of fire. This drying of forests is exacerbated during ENSO events. In the El Niño of 1997-98, researchers estimate that over half of forests burnt in the Brazilian Amazon during that time were a product of the unintentional spread of fire due to extremely dry conditions. Research on the extent of biomass burning and cumulative trace gas emissions in Amazônia has paid insufficient attention to the growing proportion of unintentional fires and the human dimensions of this growing vulnerability. Human vulnerability to climate varies among social groups, depending on property size, land use and technology used, and their access to forecasting information. It is not widely recognized that Amazonian forests can catch fire. This misperception on the part of scientists, policy makers, and forecasters may be implicated in the way information is communicated to end-users. Our goal was to reconstruct the timing, content and dissemination of forecasts for the 1997-98 ENSO, trace household responses, and evaluate land-cover change in order to improve dissemination and future use of forecasts, reduce socioeconomic losses due to drought, and minimize spread of fire into forests.

To accomplish these objectives, a combination of social and environmental field research methods and analysis of remotely-sensed data were used. Field methods included archival and survey research to reconstruct the history of land use and determine: 1) people's assessment of changing local fire spread and its relation to ENSO forecasts, 2) people's trust in the forecasts by source, 3) how the use of the forecasts was affected by fiscal policy and by the growing health risks from the heavy smoke from fires, 4) the changing economic value of forest in each area, and 5) to measure the extent of unintentional fire spread. Interviews with policy and decision makers assessed their awareness of ENSO forecasts, and their understanding of their relevance for the study areas. Remotely-sensed data was used to track changes in land cover, and changing land use as influenced by forecasts and changing moisture levels. The study also examined the growth of cities in these two regions, and what role urbanization may play in exacerbating or ameliorating this situation.

We selected a medium-sized city Santarém (population~260,000) and a small city Altamira (population~85,000) and their rural periphery. The number of medium and small Amazonian cities has grown rapidly and they have notable importance in land-use and land-cover change because of growing rural-to-urban migration, and the growing proportion of urbanites' wealth in rural real estate. The process of assessment by individuals and groups as they organize to bring about reduced vulnerability to the consequences of ENSO events and to the spread of fire was of particular interest in this study. The last ENSO was accurately forecast, 85% of the population in the study areas regularly view television news programs that include information about ENSO, and yet, little is known of the coping strategies of this past forecast in order to understand how best to prepare the population for future ones, and reduce their growing vulnerability from fires.

## B. Objective of Research Project:

This study was built upon long-term research in Amazônia by the co-PIs, focusing upon the impact of different land-use strategies and of soil fertility upon differential rates of forest succession (in five areas, one of them Altamira), and a previous study assessing the use of fire as a land management tool by a small sample of rural dwellers in four communities south of Santarém (Sorrensen 1998; Moran and Brondizio 1998; Moran et al. 1994, 1996; Brondizio et al. 1994, 1996). These studies have pointed to the importance of biophysical factors (edge effects, amount and dryness of biomass, size of the clearing, soil fertility) and of social processes (institutions, available labor and capital, age/gender composition of households, perception of resources) in understanding changing land use and land cover (cf. Also Cochrane and Schulze 1998; Holdsworth and Uhl 1997; Possingham et al. 1995; Woods 1989). The specific objectives of the study were to:

1. study two field sites in the Brazilian Amazon in order to assess the accuracy of ENSO predictions in forecasting the regional patterns of precipitation and the risk of each area to the spread of fire;
2. identify coping strategies used by stakeholders to contend with ENSO events (including indigenous forecasting techniques) and the differential vulnerability of different groups of stakeholders;
3. assess the effects of ENSO events on vegetation, livestock, crops, and different social groupings in the two study regions;
4. understand the changing perceptions and trust in the forecasts by land users and urban dwellers in small and medium-sized cities, and whether they relate these forecasts= relevance to economic and environmental losses and health risks; and
5. develop improved ways to reduce vulnerability of most at-risk groups by bringing stakeholders, forecasters and policy-makers together to discuss this study=s findings and implement local ENSO monitoring.

## C. Approach:

Considerable attention was given to developing a questionnaire, allowing for the collection of accurate information for analysis, enhanced the efficiency of data entry, reducing errors in data entry, and permitting comparison between our two study areas. The final survey consisted of 140 questions divided in six main sections:

1. General: characteristics of male household and his relationships to the lot
2. Characteristics of the Lot: information of land use in general
3. El Niño: perception and reactions
4. Land Use: fire use and fire management
5. Labor and technology
6. Social organization and credit

We also used a questionnaire for the female head of the household, mainly based on the questionnaire used in an earlier study on demographic dimensions of deforestation. We have radically simplified this very extensive demographic instrument to meet the needs of this project. Its aim was to collect information on the age and gender structure of households, and the differences they may have from the male head of household in handling forecast information and their perceptions of risk. Other questions were introduced to capture a picture of the household economy and as a check on the information obtained from the male head of household. We developed a database for facilitating the data entry, and drew our stratified random sample so that it captured the differences over time in the land use developments in the region. To do so, a software application was constructed to facilitate encoding, validation, and retrieval of questionnaire data. Validation of data, based either on its format or its deviation from the distribution of current entries, helped to eliminate errors in data entry. Retrieval of the data was carried out on a record by record basis and by user-specified datasets. This application stored information about each of the questions for potentially several questionnaires and the responses to each for each household and was deployed over a network as several clients with common backend data storage. This application included both a native GIS interface with ESRI ArcView

to permit either simple orientation of the user or analysis. We completed data entry and data cleaning for all of the male head of household surveys (N=442) at both sites, and then completed the data entry and data cleaning for the female head of household surveys. We accelerated the effort on the male surveys because they dealt more directly with the issues of the level of trust about the forecast and the economic losses resulting from ENSO events.

During analysis, differences in perception between rural and urban residents were examined, and their changing strategies over time and space. It is assumed that greater measures may be taken to prevent fires as one gets closer to the city. Whether this is true, or whether the wind patterns make such practices ineffective, were examined. Both cities= airports have experienced closings due to smoke from fire, and health risks have been noted by local physicians due to pervasive smoke for many consecutive days. Data collected on changes in respiratory ailments during El Niño years from the public health service, hospital, and other local agencies responsible for maintaining health records were examined to look for trends during ENSO and non-ENSO years.

A key to making climate prediction more socially useful lies in how one develops links between those who produce the forecasts and those who benefit from the forecasts. The users need to be engaged in this process, and this becomes a serious challenge in an area such as Amazônia, with proverbially poor road infrastructure and wide gaps in education and economic status. It is hypothesized that urban merchants who own rural properties will not necessarily be the first to hear the forecast of an oncoming El Niño, but that they will be the first to take coping strategies because of their greater trust in the forecast--the likelihood that they would lose the most from the spread of fires, and their greater capability to shift production priorities because of greater total wealth. Small rural producers will vary in their response to the forecast. Those with young families are less likely to shift production strategies than older household heads because of the lack of capital, as compared with the greater flexibility and modest capital available to older households whose cropping strategy is more diversified to start with. As part of this study we had two workshops, one in Altamira and one in Santarém, where we brought the forecasting community together with the user communities to undertake a process of mutual education and discussion as to how best to transmit the information needed by each group in a workshop. The results of this study will go a long way toward changing how forecasts are used by people of these two regions, and provide a strategy for improving forecasts in other parts of the Amazon Basin. Jointly, we developed an El Niño Prediction Kit that cost-effectively engages local stakeholders in monitoring the magnitude and risk of future ENSO-related droughts.

In a series of workshops in Santarém and Altamira we distributed rain gauges and a short guide for users including our collected data on ENSO and non-ENSO years to educate stakeholders on how to interpret the rain fall data they will collect and begin to pay attention to anomalous patterns and alert them through our data to the economic costs incurred by those who took part in the study.

## **II. Interactions**

### **A. Description of Interactions with Decision Makers:**

We interacted with radio and TV station managers to find out how they obtain forecast information and transmit it. We interacted with agricultural extension services and the agricultural research organization to find out how their information does, or does not, make its way to farmers. During Fall 2002 the PI on the grant gave five TV interviews where he explained the study, and provided some information on ENSO events. This proved to be one of the only programs actually mentioning the mild El Niño that was taking place at the time. We collaborated with EMBRAPA in Santarém and Altamira, both of which in the past have been in charge of collecting precipitation and other climate data. In Altamira they organized an event in June 2004--a 30-year retrospective of the PI's work in the region--to which community leaders and heads of organizations came. This retrospective is in addition to the climate forecast workshop with stakeholders. In 2003, three workshops were held with local stakeholders in three communities (Sao Jorge, Belterra, and Mojuí dos Campos). This series was made possible by close collaboration with the Institute Senna and Emater (the rural extension service). An El

Niño prediction kit was distributed to over 30 stakeholders, including a rain gauge so as to increase the spatial distribution of precipitation data and promote concern for ENSO-related droughts. In Altamira in June 2004, two workshops were conducted in the city and at another community, Medicilândia. Thirty-seven rain gauges and El Niño prediction kits were distributed and the preliminary analyses were shared with local stakeholders, both farmers and local agency representatives.

**B. Description of Interactions with Climate Forecasting Community:**

We have been in contact with CPTEC, Brazil's climate forecasting community in Sao Paulo. However, they agree that current models used cannot provide local forecasts. The limited number of weather stations exacerbates this problem.

**C. Coordination with Other Projects of the NOAA Climate and Societal Interactions Division:**

We have to date not had interactions with other projects, except for the one led by Kathy Galvin in Africa, and the one led by Tim Finan in Northeast Brasil.

**III. Accomplishments**

**A. Brief Discussion of Research Tasks Accomplished:**

We had one field season in 2001 and one in 2002. In Summer 2002 we completed data collection at the Altamira Site, and in the Fall 2002 we completed data collection in Santarém. We completed the collection of 271 household surveys at Santarém, and another 171 households at the Altamira site for a total of 442 households. This work required the efforts of a large team for several weeks in the Amazon using two to three vehicles. A pair of interviewers went to each household--one to interview the male head of household, the other the female head of household. We also collected GPS information to accurately locate each household in the satellite images, and visited their farm fields to ensure that we understood their activities. We carried out the remotely-sensed analysis of land cover classes and change, and verified the accuracy of the classification in the field. We acquired a more recent image (2001) which we took with us in the second field season. We worked on improving the property grid map that is overlaid over the time series of Landsat data and contacted local agencies to try and find some better maps of the properties. Some additional maps were located and we have now entered those. We have collected archival data from newspapers, visited radio stations and TV stations to discuss their forecast information. We collected some histories of the two study regions and visited archives, such as the Centro Cultural Bonarges Sena which has a good collection of newspapers, some radio transcripts, and other valuable materials. They helped us coordinate the workshops.

We visited a number of relevant government agencies and met with the heads and relevant staff. The agencies visited included the Colonization and Settlement Agency (INCRA), the Bank of Brazil, Brazil's Environmental Protection Agency (IBAMA), the Geography and Statistics Bureau (IBGE), the national agricultural research foundation (EMBRAPA), and the extension service (EMATER). We also visited with intermediaries in marketing commodities and with merchants to assess product prices, market chains, seasonal variation in prices, and strategies to improve marketing of commodities.

To improve image classification we collected over 100 additional training samples, and we bought IKONOS satellite data, at 1 to 4 meter resolution to improve our assessment of fire risk at community level. To assess accidental fire risk we monitored 40 plots before and after the burning season. Training samples were applied for a target vegetation and the adjacent areas. In addition, a detailed interview with the owner of the area was undertaken to get information on fire management, land use history, farm management, techniques used to manage fire, and the number of days without rain used to decide on the timing of the burn. We used GPS devices to map the target areas for burns, and the location of accidental fires. A detailed protocol was used to assess the quality of the burn, the frequency of accidental fires, and the presence or absence of fire control techniques.

### C. Elaboration of Key Findings:

Nearly half of the households sampled did not remember a dry or ENSO year ever. We believe this is because 2000 and 2001 were spectacularly wet years, and this has erased memories, and impacts, from the 1997-98 event. We have been quantifying the fire scars in the study area for the 1997-98 event and they are extensive. The economic losses remembered are loss of fences and barbed wire mostly, but grass seems to recover quickly with the arrival of rains. In Santarém there are few losses of perennial crops due to their relative absence, while in Altamira where cocoa plantations exist the farmers have forsworn the use of fire since the losses from the 1982 ENSO. There is very little trust in the forecast information, but this is largely due to the generality of the forecast that is transmitted in the media (e.g. "It will rain today in the Amazon..."). Many people indicated that they thought science could improve the quality of the forecasts, but that it needed to be more local in nature. The role of the media seems crucial in the salience of ENSO events, with 1997-98 receiving the most attention (and is still vividly remembered for that reason), while the current year ENSO was never discussed as such in the media and is simply not recognized by local peoples.

### D. List of Publications and Presentations arising from the Project:

The following publications and presentations have arisen from this work to date:

#### In Press:

- Sorrensen, C. Contributions of Fire Use Study to Land Use/Cover Change Frameworks: Understanding Landscape Change in Agricultural Frontiers. *Human Ecology* 32:4:395-420.
- Moran, E.F., E. Ostrom and J.C. Randolph. Ecological Systems and Multitier Human Organizations. In: *UNESCO/Encyclopedia of Life Support Systems*. Oxford, UK: EOLSS Publishers.
- Moran, E.F. Progress in the Last Ten Years in the Study of Land Use/Cover Change and the Outlook for the Next Decade. In *Studying the Human Dimensions of Global Environmental Change*. A. Diekmann, T. Dietz, C.C. Jaeger, and E.A. Rosa (eds.). Cambridge, MA: MIT Press.
- Lu, D., Mausel, P., Batistella, M., and Moran, E. Land Cover Binary Change Detection Methods for Use in the Moist Tropical Region of the Amazon: A Comparative Study. *International Journal of Remote Sensing*.
- Lu, D., E.F. Moran, P. Mausel, and E. Brondizio. Comparison of Aboveground Biomass Across Amazon Sites, In: *Seeing the Forest and the Trees: Human-Environment Interactions in Forest Ecosystems*, edited by E. Moran and E. Ostrom, Oxford University Press.
- Lu, D., Batistella, M., and Moran, E. Satellite Estimation of Aboveground Biomass and Impacts of Forest Stand Structure. *Photogrammetric Engineering and Remote Sensing*.
- Lu, D., Batistella, M., Moran, E., and Mausel, P. Application of Spectral Mixture Analysis to Amazonian land-Use and Land-Cover Classification. *International Journal of Remote Sensing*.
- Moran, E.F. The Development of the International Land-Use and Land-cover Change Program (LUCC). (Chapter 1) In: *Land Change Science: Observing Monitoring, and Understanding Trajectories of Change on the Earth's Surface*. C. Justice, et al. (eds.). Kluwer Pubs. (with B.L Turner II and D. Skole)
- Moran, E.F. Linking Pixels and People. (Ch. 23) In: *Land Change Science: Observing Monitoring, and Understanding Trajectories of Change on the Earth's Surface*. C. Justice, et al. (eds.). Kluwer Pubs. (with R. Rindfuss, B.L. Turner II, B. Entwisle, S. Walsh)
- Moran, E.F. Regional Synthesis and Land Change Trajectories. (Ch. 26) In: *Land Change Science: Observing Monitoring, and Understanding Trajectories of Change on the Earth's Surface*. C. Justice, et al. (eds.). Kluwer Pubs. (with Mustard, Fisher, R. DeFries)
- Moran, E.F. The Relevance of Land Change to the Human Sciences. (Ch. 27) In: *Land Change Science: Observing Monitoring, and Understanding Trajectories of Change on the Earth's Surface*. C. Justice, et al. (eds.). Kluwer Pubs. (with B.L. Turner, R. Rindfuss)

## 2004

- Lu, D., P. Mausel, M. Batistella, and E.F. Moran. Comparison of Land-Cover Classification Methods in the Brazilian Amazon Basin. *Photogrammetric Engineering and Remote Sensing* 70 (6):723-731.
- Lu, D., P. Mausel, E. Brondizio, and E.F. Moran. Relationships Between Forest Stand Parameters and Landsat TM Spectral Responses in the Brazilian Amazon Basin. *Forest Ecology and Management* 198:149-167.
- Lu, D., P. Mausel, E. Brondizio, and E.F. Moran. Change Detection Techniques. *International Journal of Remote Sensing* 25 (12): 2365-2407.
- Boucek, B. and E.F. Moran. Inferring the Behavior of Households from Remotely Sensed Changes in Land Cover: Current Methods and Future Directions. In: *Spatially Integrated Social Science*. M.F. Goodchild and D.G. Janelle (eds.). Oxford University Press, New York. Pp. 23-47.
- Lu, D.; M. Batistella, and E.F. Moran. Multitemporal spectral mixture analysis for Amazonian land-cover change detection. *Canadian Journal of Remote Sensing* 30(1): 87-100.

## 2003

- Moran, E.F., A. Siqueira and E. Brondizio. Household Demographic Structure and its Relationship to the Amazon Basin. In: *People and the Environment: Approaches to Linking Household and Community Surveys to Remote Sensing and GIS*. J. Fox, V. Mishra, R. Rindfuss, and S. Walsh (eds.) 2003. Kluwer Academic Press. Pp. 1-30.
- Batistella, M., S. Robeson and E.F. Moran. Settlement Design, Forest Fragmentation, and Landscape Change in Rondônia, Amazônia. *Photogrammetric Engineering & Remote Sensing* 69(7): 805-812.
- Lu, D., P. Mausel, E. Brondizio, and E.F. Moran. Classification of the successional forest stages in the Brazilian Amazon Basin. *Forest Ecology and Management* 181:301-312.
- Siqueira, A., S.D. McCracken, E. Brondizio, and E.F. Moran. Women and Work in a Brazilian Agricultural Frontier. In: *Gender at Work in Economic Life*. Edited by Gracia Clark. Altamira Press, New York. Pg. 243-267.
- Lu, D., E.F. Moran, and M. Batistella. Linear mixture model applied to Amazonian vegetation classification. *Remote Sensing of Environment* 87:456-469.

## 2002

- Sorrensen, C. Frontier Spaces of Vulnerability: Regional Change, Urbanization, Drought and Fire Hazard in Santarém, Pará, Brazil. *Urban Ecosystems* 6:1-2:123-144.
- Simmons, C., Sorrensen, C., and Walker, R. Urban rural linkages and environmental change: Addressing the human dynamics of urban ecologies. *Urban Ecosystems* 6:2-1:5-8.
- Simmons, C., Sorrensen, C. and Walker, B. (Eds.). Ecological Implications of Urban-Rural Linkages in Developing Countries. Special Issue. *Urban Ecosystems* 6:1-2.
- Evans, T.P. and E.F. Moran. Spatial Integration of Social and Biophysical Factors Related to Landcover Change. In: *Population and Environment: Methods of Analysis* (A Supplement to Vol. 28, Population and Development Review, W. Lutz, A. Prskawetz, and W.C. Sanderson eds.). Pp. 165-186.
- McCracken, S.D., B. Boucek, and E.F. Moran. Deforestation Trajectories in a Frontier Region of the Brazilian Amazon. In: *Linking People, Place, and Policy: A GIScience Approach*. S.J. Walsh and K. Crews-Meyer (eds) Kluwer.:Boston. Pp. 215-234.
- Lim, K., P.J. Deadman, E.F. Moran, E. Brondizio, and S. McCracken. Agent-Based Simulations of Household Decision Making and Land Use Change near Altamira, Brazil. In: *Integrating Geographic Information Systems and Agent-Based Modeling Techniques for Simulating Social and Ecological Processes*. H. Randy Gimblet (ed.) 2002. Oxford University Press. Pp. 277-310.
- Lu, D., P. Mausel, E.S. Brondizio, and E.F. Moran. Change Detection of Successional and Mature Forests Based on Forest Stand Characteristics Using Multitemporal TM Data in Altamira, Brazil. *Proceedings from ACSM-ASPRS Annual Conference*. Washington, D.C.
- Lu, D., P. Mausel, E.S. Brondizio, and E.F. Moran. Assessment of atmospheric correction methods for Landsat TM data applicable to Amazon basin LBA research. *International Journal of Remote Sensing* (23)13: 2651-2671.
- Lu, D., P. Mausel, and E.F. Moran. Linking Amazonian Secondary Succession Forest Growth to Soil Properties. *Land Degradation & Development* 13:331-343.

- Lu, D., M. Batistella, and E.F. Moran. Linear Spectral Mixture Analysis of TM Data for Land-Use and Land-Cover Classification in Rondonia, Brazilian Amazon. *Proceedings of the ISPRS Commission IV Symposium. Geospatial Theory, Processing and Applications*. Ottawa, Canada.
- Lu, D., P. Mausel, E.S. Brondizio, and E.F. Moran. Above-Ground Biomass Estimation of Successional and Mature Forests Using TM Images in the Amazon Basin. In: *Advances in Spatial Data Handling: 10th International Symposium on Spatial Data Handling*. (D.E. Richardson and P. van Oosterom eds.) Pp. 183-196.
- Brondizio, E.S.; S. McCracken; E.F. Moran; A.D. Siqueira,; D. Nelson; and C. Rodriguez-Pedraza. The Colonist Footprint: Toward a Conceptual Framework of Land Use and Deforestation Trajectories among Small Farmers in the Amazonian Frontier. In: *Deforestation and Land Use in the Amazon*. C.H. Wood and R. Porro (eds.) Univ. Press of Florida, Gainesville. Pg133-161.
- McCracken, S.; A.D. Siqueira; E.F. Moran; and E.S. Brondizio. Land Use Patterns on an Agricultural Frontier in Brazil: Insights and Examples from a Demographic Perspective. In: *Deforestation and Land Use in the Amazon*. C.H. Wood and R. Porro (eds.) Univ. Press of Florida, Gainesville. Pg 162-192.
- Moran, E.F.; E.S. Brondizio; and S. McCracken. Trajectories of Land Use: Soils, Succession, and Crop Choice. In: *Deforestation and Land Use in the Amazon*. C.H. Wood and R. Porro (eds.) Univ. Press of Florida, Gainesville. Pg 193-217.

## 2001

- Evans, T.P., A. Manire, F. de Castro, E.S. Brondizio, and S.D. McCracken. A dynamic model of household decision-making and parcel level land cover change in the eastern Amazon. *Ecological Modelling* 143:95-113.

## 2000

- Moran, E.F., E.S. Brondizio, J. Tucker, M.C. Silva-Forsberg, I. Falesi, and S. McCracken. Strategies for Amazonian Forest Restoration: Evidence for Afforestation in Five Regions of the Brazilian Amazon. A. Hill (ed.). London. In: *Amazonia at the Crossroads* (pp. 129-149),
- Moran, E.F., E.S. Brondizio, J.M. Tucker, M.C. Silva-Forsberg, S. McCracken, and I. Falesi. Effects of soil fertility and land-use on forest succession in Amazônia. *Forest Ecology and Management* 139: 93-108.
- Batistella, M.; E. Brondizio, E.F. Moran. Comparative Analysis of Landscape Fragmentation in Rondonia, Brazilian Amazon. *International Archives of Photogrammetry and Remote Sensing*. Vol XXXIII, Part B7. Pp. 148-155.

## Submitted:

- Emilio F. Moran, Ryan Adams, Bryn Bakoyéma, Stefano Fiorini, and Bruce Boucek. Human Strategies for Coping with El Niño Related Drought in Amazonia. Submitted to *Climatic Change*.

## Papers in Progress:

- Sorrensen, C. Unpublished manuscript. "Displacing Resistance: Place and Rural Change in the Nova Fronteira Agrícola of Santarém, Pará, Brazil"
- Schneider, A. and Sorrensen, C. Unpublished manuscript. "Potential Hazards for Brazilian Fire Policy: Implications for Conservation and Development Initiatives"

## Presentations/Sessions Organized:

- Moran, E.F. Presenter, "Science Planning for the Terrestrial Human Environment System." Land Use Cover Change Scientific Steering Committee meeting. Brussels, Belgium. April 11-14, 2002.
- Moran, E.F. Co-Organizer, Workshop: "Ecosystem Responses to Unpredictable Events in Temperate Forests." Indiana University, Bloomington, IN. April 19-20, 2002.
- Moran, E.F. Co-Organizer: "Powerful GIS Tools to Advance Spatial and Temporal Analysis in Anthropological Research." American Anthropological Association annual meeting. New Orleans, LA. Nov. 20-24, 2002.
- Moran, E.F. Organizer, Session entitled: "Land Use, Land Cover change, and Demographic Processes." 2004 Annual Meeting of the Population Association of America. Boston, MA. April 1-3, 2004.

- Sorrensen, C. "Rural Property Rights in an Era of Globalization", upcoming session co-organized and co-chaired with Nora Haenn for the Latin American Studies Association, Las Vegas, NV, October 6-9, 2004.
- Sorrensen, C. "Conservation, Fire Policy and Land Tenure in the Brazilian Amazon", paper to be presented at the upcoming Latin American Studies Association, Las Vegas, NV, October 6-9, 2004.
- Sorrensen, C. "Environmentalism, Crisis Events, and the Politics of Fire Hazard in the Brazilian Amazon", paper presented at the Annual Meetings of the Association of American Geographers, Philadelphia, PA March 15-19, 2004.
- Sorrensen, C. "Rural Change and the Industry of Urban Land Invasion in the Brazilian Lower Amazon", paper presented at the Annual Meetings of the Association of Pacific Coast Geographers, Portland, Oregon, Sept. 17-20, 2003.
- Sorrensen, C. "Displacing Actions: Place and Rural Change in the Brazilian Lower Amazon", paper presented at the Annual Meetings of the Association of American Geographers, New Orleans, Louisiana, March 4-9, 2003.
- Sorrensen, C. "Place Identity, Environmental Change, and Political Ecology", session co-organized and co-chaired with Alec Brownlow at the Annual Meetings of the Association of American Geographers, New Orleans, Louisiana, March 4-9, 2003.
- Sorrensen, C. "Analysis of Urbanization and Related Forest Fragmentation in the Brazilian Lower Amazon Using Remote Sensing", co-author of poster (with M. Villarreal) presented at the Annual Meetings of the Association of American Geographers, New Orleans, Louisiana, March 4-9, 2003.
- Sorrensen, C. "Place and the Creation of the Nova Fronteira Agrícola: A Case Study of Santarém, Pará", paper presented at the Rocky Mountain Latin American Studies Conference, Phoenix, Arizona. February 19-22, 2003.
- Sorrensen, C. "The Industry of Land Invasion: Tracing Urban Rural Peripheries in the Brazilian Lower Amazon", paper presented at the Conference of Latin American Geographers. Tucson, Arizona. January, 6-8, 2003.

#### Invited Speaking Engagements:

#### **2000**

- Moran, E.F. "Human Ecosystems: Linking Biophysical and Social Processes." LTER presentation. Arizona State University, Tempe, AZ. January 19.
- Moran, E.F. "The Dynamics of Land Use/Land Cover Change-The Need for a Historical Perspective." BIOME 300. Bern, Switzerland. March 5-7.
- Moran, E.F. "Change in Forest Ecosystems: A Case Study at Multiple Scales," Population and Environmental Change in the Americas: Cross-site Comparisons," and "Population and Environmental Change in the Americas." IGBP Land-Use and Land Cover Change Workshop on Human modification of the biosphere: Key Drivers of Land-use/cover Change Processes. Stockholm, Sweden. March 13-15.
- Moran, E.F. "Results of Studies on Tropical Moist and Tropical Dry Forests of the Americas." Michigan State University, East Lansing, MI. March 29-30.
- Moran, E.F. "Advances in Property-Level Analysis of Land use and Land Cover Change Seminar Series." Pattern to Process: Global International Dimensions of Land Use and Cover Change. Michigan State University, East Lansing, MI. March 29-30.
- Moran, E.F. "Human and Physical Dimensions of Land Use/Cover Change in Amazônia: Forest Regeneration and Landscape Structure." 4<sup>th</sup> NASA Land Cover Land Use Change Science Team Meeting, Reston, VA. April 3-5.
- Moran, E.F. "Exploring tropical deforestation and land use." Association of American Geographers annual meeting. Pittsburgh, PA. April 4-8.
- Moran, E.F. "Land Use and Land Cover Change in Amazônia: Biophysical, Demographic, and Social Drivers." National Center Geographic Information and Analysis and Department of Geography, University of California. Santa Barbara, CA. May 3.
- Moran, E.F. "Mudanças no uso da Terra e na Cobertura Vegetal na Amazônia." IPAM. Belem, Para, Brazil. June 28.

## 2001

- Moran, E.F. "The Developmental Cycle of Domestic Groups and Amazonian Deforestation" presented at the Population Association of American annual meeting held March 29-31, and at the Large-scale Biosphere-Atmosphere Experiment in Amazonia conference. Atlanta, GA. February 12-14.
- Moran, E.F. "What's Driving Land Use and Land Cover Change? Myths and Realities." Presented at the American Association for the Advancement of Science annual meeting, session on Earth System Science. San Francisco, CA. February 15-20.
- Moran, E.F. "Population and the Environment in the Amazon Basin." Princeton University, Environmental Research Institute. Princeton, NJ. October 12.
- Moran, E.F. "Household Demographic Structure and its Impact on the Trajectories of Deforestation in the Amazon." Brown University. Providence, RI. October 25.
- Moran, E.F. "Land use and Land Cover Change and the Carbon Cycle." National Research Council meeting, Washington DC. November 5.
- Moran, E.F. "LUCC Progress 2001." Land Cover and Land Use Change, Tropical and Subtropical Workshop. NASA Science Team. Washington, DC. November 19.
- Moran, E.F. "Human and Physical Dimensions of Land Use/Cover Change in Amazônia Forest Regeneration and Landscape Structure." Land Cover and Land Use Change, Tropical and Subtropical Workshop. NASA Science Team. Washington, DC. November 20.
- Moran, E.F. "Global Environmental Change and the Ecosystem Perspective." Invited session. American Anthropological Association annual meeting. Washington, DC. November 29.
- Sorrensen, C. "Fire Hazard in the Amazon Rainforest", Latin American Studies Program environmental lecture series on Globalization, Environmental Change, and Communities in Latin America. California State University, Los Angeles, April 2001.

## 2002

- Moran, E.F. "Deforestation Trajectories in a Frontier Region of the Brazilian Amazon". Invited session: "Remote Sensing and GIS Applications for Linking People, Place, and Policy." Association of American Geographers annual meeting. Los Angeles, CA. March 19-24.
- Moran, E.F. "People and Pixels: Advances in Linking Social Sciences and Spatial Data through Remote Sensing." Invited lecture. Ohio State University, Columbus, OH. June 4.
- Moran, E.F. "Population and Environment Surprises in the Amazon Basin: Deforestation, Land Cover Change and the Structure of Households." Environmental Policy Initiative seminar. Ohio State University, Columbus, OH. June 4.
- Moran, E.F. "Deforestation Trajectories in a Frontier Region of the Brazilian Amazon." 2<sup>nd</sup> LBA Open Science conference, Manaus, Brazil. July 7-10.
- Moran, E.F. "Dimensoes Humanas das Mudancas na Cobertura Vegetal e Uso da Terra." Embrapa Satellite Monitoring seminar. Campinas, Sao Paulo, Brazil. August 6.
- Moran, E.F. "CIPEC: A center of excellence on human dimensions of global change." INPE. Seminar. Sao Jose dos Campos, Sao Paulo, Brazil. August 7.
- Moran, E.F. "Ecologia Humana e o Uso da Terra." SENAC seminar, Sao Paulo, Brazil, August 9.
- Moran, E.F. "Dimensoes Humanas da Mudanca Ambiental Global: A proxima decada." SENAC seminar. Sao Paulo, Brazil. August 10.

## 2003

- Moran, E.F. "Human Strategies for Coping with ENSO and Growing Flammability of Forests in Amazonia." Association of American Geographers annual meeting. New Orleans, LA. March 7.
- Moran, E.F. "Science Planning or the Terrestrial Human Environment System." Land Use Cover Change Scientific Steering Committee meeting. Banff, Canada. June 17-26.
- Moran, E.F. "Land Science Plan. Challenges Ahead." International Geosphere-Biosphere Programme Congress, Banff, Canada. June 18-25.
- Moran, E.F. "The Human-Environment Nexus: Progress in the Past Decade in the Integrated Analysis of Human and Biophysical Factors." Keynote lecture at the World System History and Global Environmental Change Congress. Lund, Sweden, Sept. 19.
- Moran, E.F. "Social Science Perspectives on Resilience." Resiliency and Change in Ecological Systems. Santa Fe Institute. Oct. 24-26.

## 2004

- Moran, E.F. "The Global Land Project" at International Human Dimensions Programme Scientific Planning Meeting. Boon, Germany. March 22, 2004
- Moran, E.F. "Deforestation and the Structure of Households." Seminar presented at the Center for the Study of Population (NEPO) at the University of Campinas, Campinas, Brazil. June 9.
- Moran, E.F. "Human Dimensions of Global Environmental Change: New Directions." Seminar presented to the Post-graduate Program in Environmental Science (PROCAM) at the University of São Paulo, SP, Brazil. June 1.
- Moran, E.F. "32 Years of Research along the Transamazon Highway: A Retrospective". Seminar presented at EMBRAPA/CPATU, Center for Agroforestry of Eastern Amazon, Belem, PA. Brazil. July 7.
- Moran, E.F. "Human Dimensions of LBA: Building on International Efforts" at III LBA Open Science Meeting, Brasilia DF, Brazil. July 26, 2004.
- Sorrsen, C. "Crisis Events and the Globalization of Fire Hazard in the Brazilian Amazon", Department of Anthropology, Brown Bag Series, Arizona State University. April 2004.
- Sorrsen, C. "The Politics of Fire Hazard in the Brazilian Amazon", Center for Latin American Studies, Brown Bag Series, University of Arizona. Spring 2002.
- Sorrsen, C. "Fires in Rainforests? Challenges to Research on the Human Dimensions of Global Environmental Change", Geography Colloquium Series, University of Arizona.

### **E. Discussion of Any Significant Deviations from Proposed Work Plan:**

The only deviation from proposed work was the dropping of the two micromet stations at the request of NOAA on the basis of the panel review and due to budget cuts. Other than that, we pursued the work as stated in the proposal. We were able to surpass the size of our sample--from the 120 at each site that we foresaw in the grant proposal, to 171 at Altamira and 271 at Santarém. This increased the power of the analysis. The larger sample in Santarém takes into account the larger population of the Santarém urban and rural areas as compared to Altamira.

## **IV. Relevance to the field of human-environment interactions**

### **A. Describe how the results of your project have furthered the field of understanding and analyzing the use of climate information in decision-making**

This is the first study to examine how ENSO affects rural and urban populations in the Amazon, and the coping strategies of the population to the 1997-98 ENSO, and we plan to see the responses also to the currently forecast ENSO. In Brazil it does not appear that the climate community felt that it was worthwhile calling this an ENSO event. However, in October some farmers were describing this ENSO as almost as severe in the early stages as the one in 1997-98.

One of the challenges of global change research is to make scientific information more relevant to decision makers at the local and regional level. This study has already begun to engage local actors (NGOs, government agencies, TV and other local media, information Abrokers@, and individual land users) in the process of evaluating the use of climate forecasts. All those interviewed expressed surprise when they discovered that the Aother@ agency also had not transmitted a local forecast. It seems each media source assumed another media was doing so! The 1997-98 ENSO is the focus of attention, but other forecasts are being used in assessing the use of information. In addition, experiments in focus groups will be conducted with the above local informants to see how severity, magnitude, and other characteristics of the forecast influence their propensity to make different decisions about the use of fire, the use of land, and other economically relevant strategies (e.g. sell cattle, not harvest crops). The impact of drought is mediated by access to adaptive technologies, crop prices, subsidies and insurance. Access to these adaptations is highly variable by region, sector, and social group. Smallholders, for example, have been noted to lack the financial and technological means to make firebreaks, but some of them do--Why? ENSO can be forecast with three to twelve-month advance notice, and the potential impacts of ENSO on agriculture, health, water resources, and fire

can be evaluated before, during and after the event. Since the Altamira-Santarém region is considered a particularly important agropastoral production zone, a goal of the study is to evaluate how well decision makers use available information and adaptive technologies to reduce vulnerability of people in the region. Does the size of the city influence the flow of information or trust in it? Are the dominant crops particularly vulnerable to precipitation shortfalls (pasture vs. tree crops)? Does one region have a more effective method of delivering climate forecast information than the other? Are special fiscal instruments made available in a timely fashion to reduce risks to all, or only some, stakeholders?

**B. Where appropriate, describe how this research builds on any previously funded HDGEC research:**

This research builds on earlier work funded by NSF and NASA. These other studies permitted accumulation of very detailed data on vegetation, soils, and land cover classes. The current work under NOAA allows us to address the coping strategies of farmers and their responses to the possibilities of widespread fire risk as a result of drought associated with ENSO. Without this support, we would not have addressed these fire-related questions.

This research was partly built from previous studies on the impact of fire use on biomass burning in the agricultural frontier of Santarém, Pará, which was funded through a NASA Earth Systems Science Fellowship which is a part of their HDGEC programs.

**C. How has your project explicitly contributed to the following areas of study?**

1. *Adaptation to long-term climate change:* The proposal addressee the question of how people adapt or cope with ENSO events. One key question was whether past ENSOs were remembered and affect future decisions taken by people. Many people seem to have forgotten the severity of the event after four years. Those who remember are very detailed in how they were affected. While last year we thought that people remembered the ENSO that took place when they first came to this region, rather than the most recent one, analysis since completion of the sample suggests that there is no statistical correlation between year of arrival and the ENSO most remembered. Ethnoclimatological forecasting techniques are used by local people and they adjust to drought through flexible agricultural cycle.
2. *Natural hazards mitigation:* We were examining what, if anything, farmers do to mitigate the risk of fire normally, and in years when ENSO is forecast. It seems that there are routine practices to mitigate the risk of fire (such as windrows), but to date very few strategies that go further than that seem to be taken.
3. *Institutional dimensions of global change:* There are some local institutions that are mobilized to ensure that people use mitigating behaviors, but this seems at present to be mostly NGOs such as IPAM, which conducts clinics and workshops on fire control.
4. *Economic value of climate forecasts:* The forecast given locally seems to be very general and of very little local relevance, so the forecast does not appear to have major economic impacts. However, once an ENSO is forecast at national scale, there are efforts to communicate specific local relevance. Hopefully, we will be able to see this during the coming field season if ENSO continues to develop. We believe increased access to scientific forecasts in the Amazon would reduce crop and animal losses during drought and prevent spread of accidental fires into rainforest. We hope that the rain gauges distributed can begin to reduce thee vulnerabilities.
5. *Developing tools for decision makers and end-users:* We hope to develop such tools after the field research and have been asking what sorts of tools will be of most value to end-users.

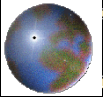
6. *Sustainability of vulnerable areas and/or people:* That is a strong focus of our work, so we did a careful assessment of the multiple resources available to households and their vulnerabilities. Subsistence farmers rely upon their ability to produce enough food and do not have adequate alternatives; providing scientific forecasts would be helpful; forest fires are better prevented by slash and burn farmers when they have good information on timing of the rains.
  7. *Matching new scientific information with local/indigenous knowledge:* We have found some local systems for forecasting. It appears that the system most widely used was developed for the conditions of Northeast Brazil and that it has poor adaptability to the precipitation patterns in these regions of the Amazon. Farmers would be glad to integrate these sources if they had access to scientific information, which they trust. They also use local forecasting techniques, which are quite varied.
  8. *The role of public policy in the use of climate information:* Clearly, we will be watching to see how public policies respond to the forecast of ENSO. Because of the mild ENSO in 2002-03, there was little response or information about it provided.
  9. *Socioeconomic impacts of decadal climate variability:* This is not part of our research.
- D. Suggestions for Future Research

Future research will need to focus more on increasing the network of micromet stations and ensuring that these data are reported and used in forecasts. Currently, the data is archived more than used and there is very little effort to make data available to users or even researchers. Efforts by NOAA, together with their Brazilian CPTEC equivalents, to have an open-access policy on precipitation data in close to real time would be a huge step forward.






## V. Graphics

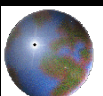
- A. Graphic over Overall Project Framework -- Not applicable

B. Key Research Results:









## Findings



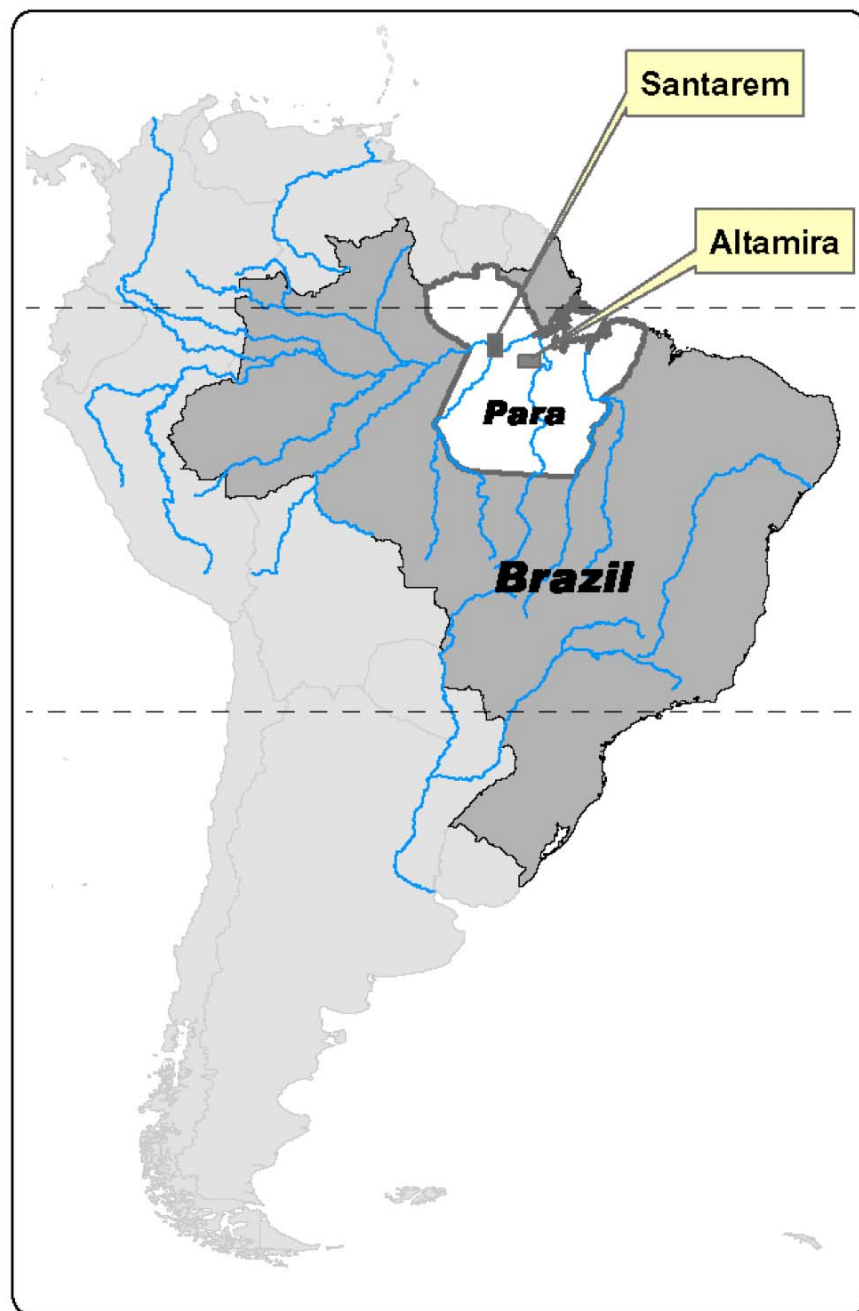


## Findings



C. Map of region covered by study

### Study Area Locations



D. Photograph from fieldwork 2001.

